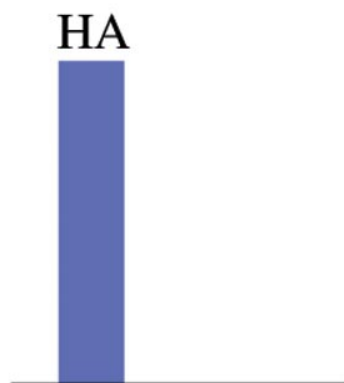
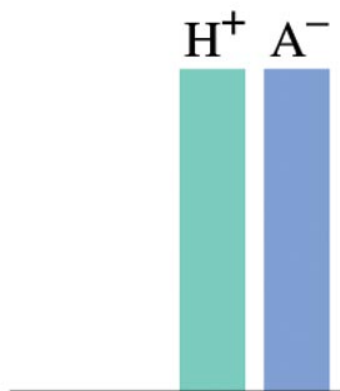


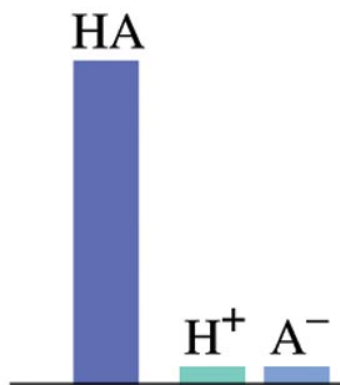
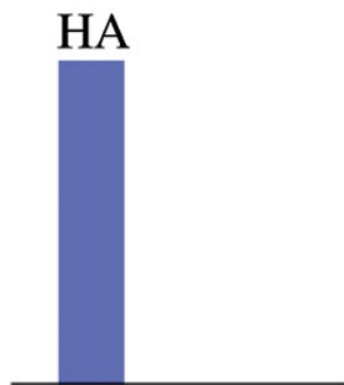
Before dissociation



After dissociation,
at equilibrium



(a) Strong Acid



(b) Weak Acid

Relative
acid
strength

↓
Very
strong
↓
Strong
↓
Weak
↓

Very
weak

Relative
conjugate
base
strength

↑
Very
weak
↑
Weak
↑
Strong
↑
Very
strong

Table 14.1 Various Ways to Describe Acid Strength

TABLE 14.1 Various Ways to Describe Acid Strength

Property	Strong Acid	Weak Acid
K_a value	K_a is large	K_a is small
Position of the dissociation (ionization) equilibrium	Far to the right	Far to the left
Equilibrium concentration of H^+ compared with original concentration of HA	$[H^+] \approx [HA]_0$	$[H^+] \ll [HA]_0$
Strength of conjugate base compared with that of water	A^- much weaker base than H_2O	A^- much stronger base than H_2O

Table 14.2 Values of K_a for Some Common Monoprotic Acids

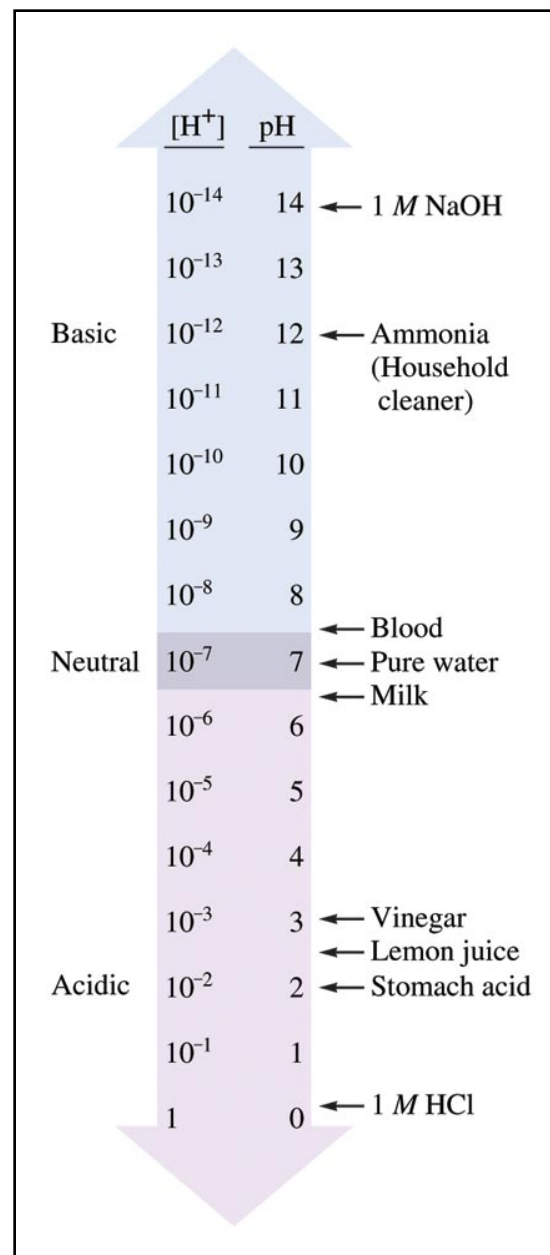
TABLE 14.2 Values of K_a for Some Common Monoprotic Acids

Formula	Name	Value of K_a^*	Increasing acid strength ↑
HSO_4^-	Hydrogen sulfate ion	1.2×10^{-2}	
HClO_2	Chlorous acid	1.2×10^{-2}	
$\text{HC}_2\text{H}_2\text{ClO}_2$	Monochloroacetic acid	1.35×10^{-3}	
HF	Hydrofluoric acid	7.2×10^{-4}	
HNO_2	Nitrous acid	4.0×10^{-4}	
$\text{HC}_2\text{H}_3\text{O}_2$	Acetic acid	1.8×10^{-5}	
$[\text{Al}(\text{H}_2\text{O})_6]^{3+}$	Hydrated aluminum(III) ion	1.4×10^{-5}	
HOCl	Hypochlorous acid	3.5×10^{-8}	
HCN	Hydrocyanic acid	6.2×10^{-10}	
NH_4^+	Ammonium ion	5.6×10^{-10}	
HOC_6H_5	Phenol	1.6×10^{-10}	

*The units of K_a are customarily omitted.

Figure 14.8

The pH Scale and pH Values of Some Common Substances



QUESTION

Butyric acid is a weak acid that can be found in spoiled butter. The compound has many uses in synthesizing other flavors. The K_a of $\text{HC}_4\text{H}_7\text{O}_2$ at typical room temperatures is 1.5×10^{-5} . What would be the pH of a 0.20 M solution of the acid?

Answer: $\text{pH} = 2.76$

QUESTION

A 0.35 M solution of an unknown acid is brought into a lab. The pH of the solution is found to be 2.67. From this data, what would be the K_a value of the acid?

Answer: 1.3×10^{-5}

QUESTION

Calculate the percent dissociation of 1.00 *M* HC₂H₃O₂.
(K_a = 1.8x10⁻⁵)

Answer: 0.42%

QUESTION

Calculate the K_a value of lactic acid ($\text{HC}_3\text{O}_5\text{H}_3$) if a 0.10 M solution is 3.7% dissociated.

Answer: 1.4×10^{-4}

Figure 14.10 The Effect of Dilution on the Percent Dissociation and $[H^+]$ of a Weak Acid Solution

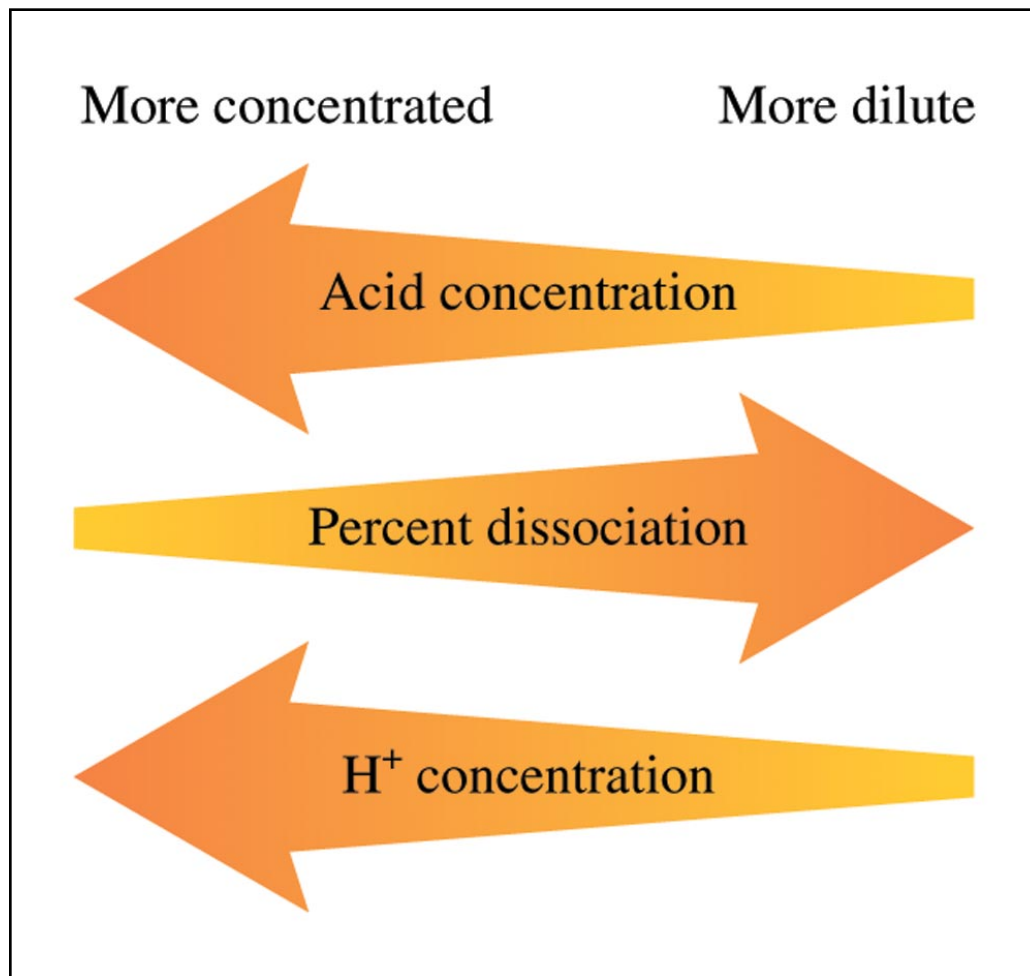


Table 14.3 Values of K_b for Some Common Weak Bases

TABLE 14.3 Values of K_b for Some Common Weak Bases

Name	Formula	Conjugate Acid	K_b
Ammonia	NH_3	NH_4^+	1.8×10^{-5}
Methylamine	CH_3NH_2	CH_3NH_3^+	4.38×10^{-4}
Ethylamine	$\text{C}_2\text{H}_5\text{NH}_2$	$\text{C}_2\text{H}_5\text{NH}_3^+$	5.6×10^{-4}
Aniline	$\text{C}_6\text{H}_5\text{NH}_2$	$\text{C}_6\text{H}_5\text{NH}_3^+$	3.8×10^{-10}
Pyridine	$\text{C}_5\text{H}_5\text{N}$	$\text{C}_5\text{H}_5\text{NH}^+$	1.7×10^{-9}

QUESTION

Calculate the pH of a 15.0 *M* solution of ammonia.
($K_b = 1.8 \times 10^{-5}$)

Answer: pH = 12.20

Table 14.4 Stepwise dissociation Constants for Several Common Polyprotic Acids

TABLE 14.4 Stepwise Dissociation Constants for Several Common Polyprotic Acids

Name	Formula	K_{a_1}	K_{a_2}	K_{a_3}
Phosphoric acid	H_3PO_4	7.5×10^{-3}	6.2×10^{-8}	4.8×10^{-13}
Arsenic acid	H_3AsO_4	5×10^{-3}	8×10^{-8}	6×10^{-10}
Carbonic acid	H_2CO_3	4.3×10^{-7}	5.6×10^{-11}	
Sulfuric acid	H_2SO_4	Large	1.2×10^{-2}	
Sulfurous acid	H_2SO_3	1.5×10^{-2}	1.0×10^{-7}	
Hydrosulfuric acid*	H_2S	1.0×10^{-7}	$\sim 10^{-19}$	
Oxalic acid	$\text{H}_2\text{C}_2\text{O}_4$	6.5×10^{-2}	6.1×10^{-5}	
Ascorbic acid (vitamin C)	$\text{H}_2\text{C}_6\text{H}_6\text{O}_6$	7.9×10^{-5}	1.6×10^{-12}	

*The K_{a_2} value for H_2S is very uncertain. Because it is so small, the K_{a_2} value is very difficult to measure accurately.

QUESTION

Ascorbic acid, also known as vitamin C, has two hydrogen atoms that ionize from the acid. $K_{a_1} = 7.9 \times 10^{-5}$; $K_{a_2} = 1.6 \times 10^{-12}$. What would be the pH, and $\text{C}_6\text{H}_6\text{O}_6^{2-}$ concentration of a 0.10 M solution of $\text{H}_2\text{C}_6\text{H}_6\text{O}_6$?

Answer: pH = 2.56; $[\text{C}_6\text{H}_6\text{O}_6^{2-}] = 1.6 \times 10^{-12} \text{ M}$

QUESTION

The K_a value for monochloroacetic acid is 1.35×10^{-3} at 25°C . Neutralizing the acid with KOH would produce the salt potassium chloroacetate. What would be the pH of a 0.110 M solution of the salt at 25°C ?

Answer: $\text{pH} = 7.96$

What about Ammonium Acetate?

TABLE 14.5 Qualitative Prediction of pH for Solutions of Salts for Which Both Cation and Anion Have Acidic or Basic Properties

$$K_a > K_b$$

pH < 7 (acidic)

$$K_b > K_a$$

pH > 7 (basic)

$$K_a = K_b$$

pH = 7 (neutral)

Table 14.6 Acid-Base Properties of Various Types of Salts

TABLE 14.6 Acid-Base Properties of Various Types of Salts

Type of Salt	Examples	Comment	pH of Solution
Cation is from strong base; anion is from strong acid	KCl, KNO ₃ , NaCl, NaNO ₃	Neither acts as an acid or a base	Neutral
Cation is from strong base; anion is from weak acid	NaC ₂ H ₃ O ₂ , KCN, NaF	Anion acts as a base; cation has no effect on pH	Basic
Cation is conjugate acid of weak base; anion is from strong acid	NH ₄ Cl, NH ₄ NO ₃	Cation acts as acid; anion has no effect on pH	Acidic
Cation is conjugate acid of weak base; anion is conjugate base of weak acid	NH ₄ C ₂ H ₃ O ₂ , NH ₄ CN	Cation acts as an acid; anion acts as a base	Acidic if $K_a > K_b$, basic if $K_b > K_a$, neutral if $K_a = K_b$
Cation is highly charged metal ion; anion is from strong acid	Al(NO ₃) ₃ , FeCl ₃	Hydrated cation acts as an acid; anion has no effect on pH	Acidic

Table 14.7 Bond Strengths and Acid Strengths for Hydrogen Halides

TABLE 14.7 Bond Strengths and Acid Strengths for Hydrogen Halides

H—X Bond	Bond Strength (kJ/mol)	Acid Strength in Water
H—F	565	Weak
H—Cl	427	Strong
H—Br	363	Strong
H—I	295	Strong

Table 14.8 Several Series of Oxyacids and Their Ka Values

TABLE 14.8 Several Series of Oxyacids and Their K_a Values

Oxyacid	Structure	K_a Value
HClO_4	$\text{H}-\text{O}-\text{Cl} \begin{array}{l} \nearrow \text{O} \\ \searrow \text{O} \end{array}$	Large ($\sim 10^7$)
HClO_3	$\text{H}-\text{O}-\text{Cl} \begin{array}{l} \nearrow \text{O} \\ \searrow \text{O} \end{array}$	~ 1
HClO_2	$\text{H}-\text{O}-\text{Cl}-\text{O}$	1.2×10^{-2}
HClO	$\text{H}-\text{O}-\text{Cl}$	3.5×10^{-8}
H_2SO_4	$\text{H}-\text{O}-\text{S} \begin{array}{l} \nearrow \text{O}-\text{H} \\ \searrow \text{O} \end{array}$	Large
H_2SO_3	$\text{H}-\text{O}-\text{S} \begin{array}{l} \nearrow \text{O}-\text{H} \\ \searrow \text{O} \end{array}$	1.5×10^{-2}
HNO_3	$\text{H}-\text{O}-\text{N} \begin{array}{l} \nearrow \text{O} \\ \searrow \text{O} \end{array}$	Large
HNO_2	$\text{H}-\text{O}-\text{N}-\text{O}$	4.0×10^{-4}

Figure 14.11

The Effect of the Number of Attached Oxygens on the O-H Bond in a Series of Chlorine Oxyacids

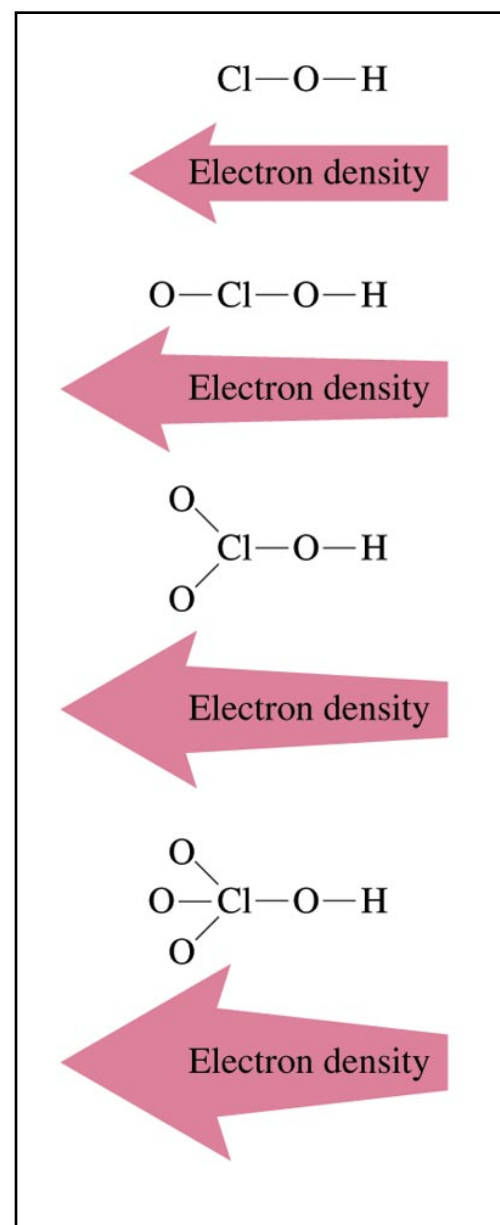


Table 14.9 Comparison of Electronegativity of X and K_a Value for a Series of Oxyacids

TABLE 14.9 Comparison of Electronegativity of X and K_a Value for a Series of Oxyacids

Acid	X	Electronegativity of X	K_a for Acid
HOCl	Cl	3.0	4×10^{-8}
HOBr	Br	2.8	2×10^{-9}
HOI	I	2.5	2×10^{-11}
HOCH ₃	CH ₃	2.3 (for carbon in CH ₃)	$\sim 10^{-15}$

Table 14.10 Three Models for Acids and Bases

TABLE 14.10 Three Models for Acids and Bases

Model	Definition of Acid	Definition of Base
Arrhenius	H^+ producer	OH^- producer
Brønsted–Lowry	H^+ donor	H^+ acceptor
Lewis	Electron-pair acceptor	Electron-pair donor